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B70 11017

SUBJECT: Statistical Analysis of Engine Gain Data - Case 320

DATE: November 6, 1970

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MEMORANDUM FOR FILE

INTRODUCTION

Analysis indicates that the S-II stage has marginal instability at 11 HZ near end of burn, and 11 HZ response has occurred in-flight. Analysis using current estimates of worst-case component gains indicates some risk of divergence. The dominant uncertainties are magnitude and variability of engine gain. Ground test data has been interpreted to indicate that engine-to-engine gain variations of ± 2 db may occur in the 10-20 HZ region. This memorandum describes an attempt to apply statistical methods to available flight data to determine the magnitude, variability and confidence limits of engine gain. This would characterize the engine and flight measurement system, and would not include any facilities effects which might be present in the ground test characterizations. Reduced data from the AS-507 flight has been used to explore the feasibility of this approach.

PROCEDURE

The flight data were analyzed as follows:

(1) Identify time periods in-flight when spectrograms show that oscillations are simultaneously present in the measurements of thrust chamber pressure and LOX pump inlet pressure on one or more engines.

(2) Obtain MSFC reduced data for 5 second time slices through these time periods, including for each measurement:

a) output vs time

b) PSD plots

(3) For each 5 second time slice in which the output vs time plot shows no obvious anomaly (data dropout or recognizable transient), and the PSD plots show a satisfactory signal-to-noise ratio for the frequency component of interest, tabulate

Time

Frequency

Pc (thrust chamber pressure oscillation amplitude)

Pos (LOX pump inlet pressure oscillation amplitude)

and Pc/Pos = engine gain.

(The preceeding operation on the AS-507 data which was available to us yields a dozen or so apparently good quality data points for engine 1 and a similar number for engine 5.)

(4) Plot Pc/Pos vs Pos, and derive statistical curve-fit and analysis of variance.

RESULTS

The attached plots show that:

(1) Application of this technique to data from AS-507 yields a well-behaved set of data.

(2) The confidence limits are much tighter than those of ground test data.

(3) The engine-to-engine gain difference is smaller than the statistical errors in the data for either engine.

RECOMMENDATIONS

Apply this approach to flight data from additional engines and vehicles to establish confidence limits on both gain and phase, and investigate the feasibility of applying the approach to measurement of structural and line components of the POGO loop.

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Attachments

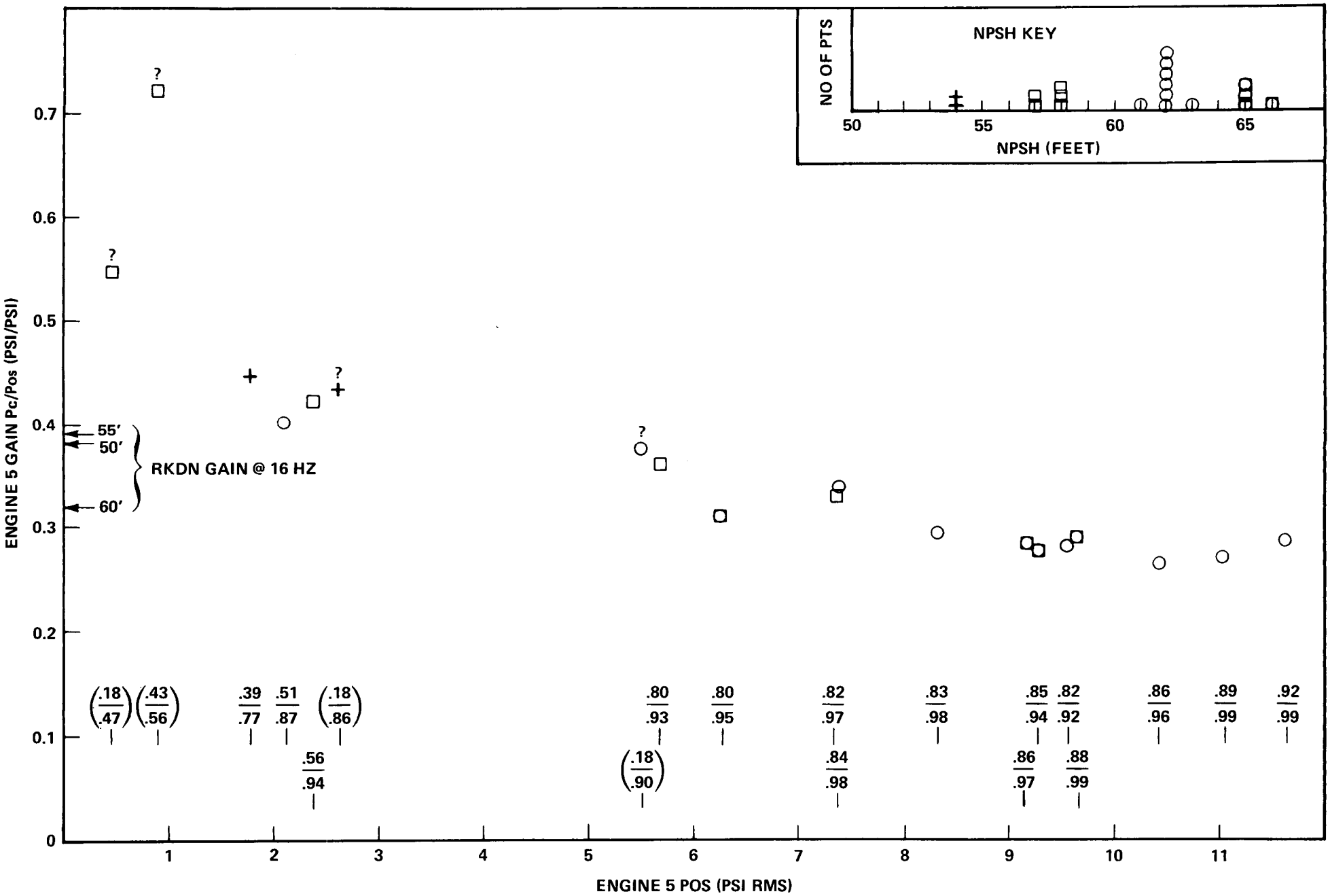

FIGURE 1 - SA-507 ENGINE NO. 5 GAIN

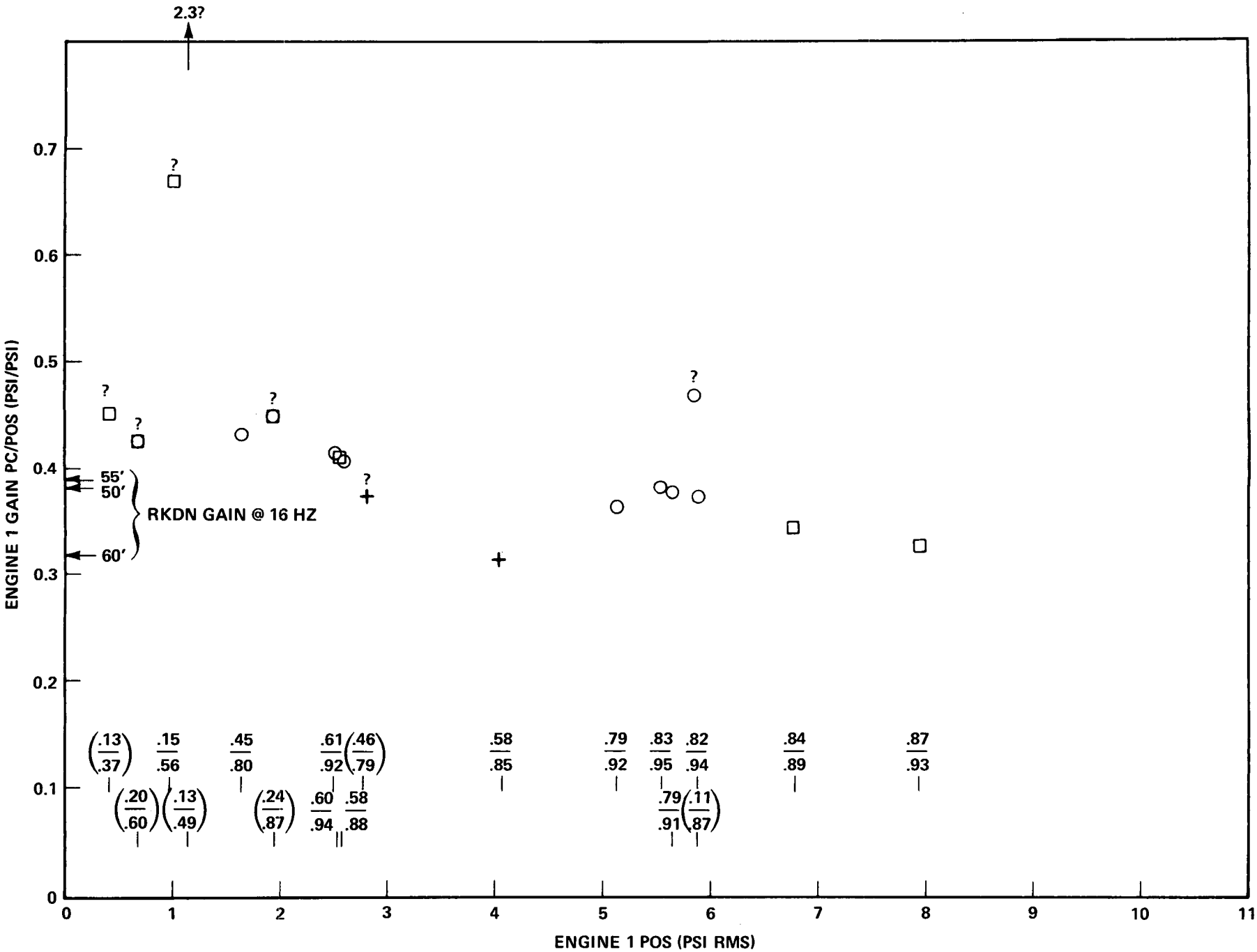

FIGURE 2 - SA-507 ENGINE NO. 1 GAIN

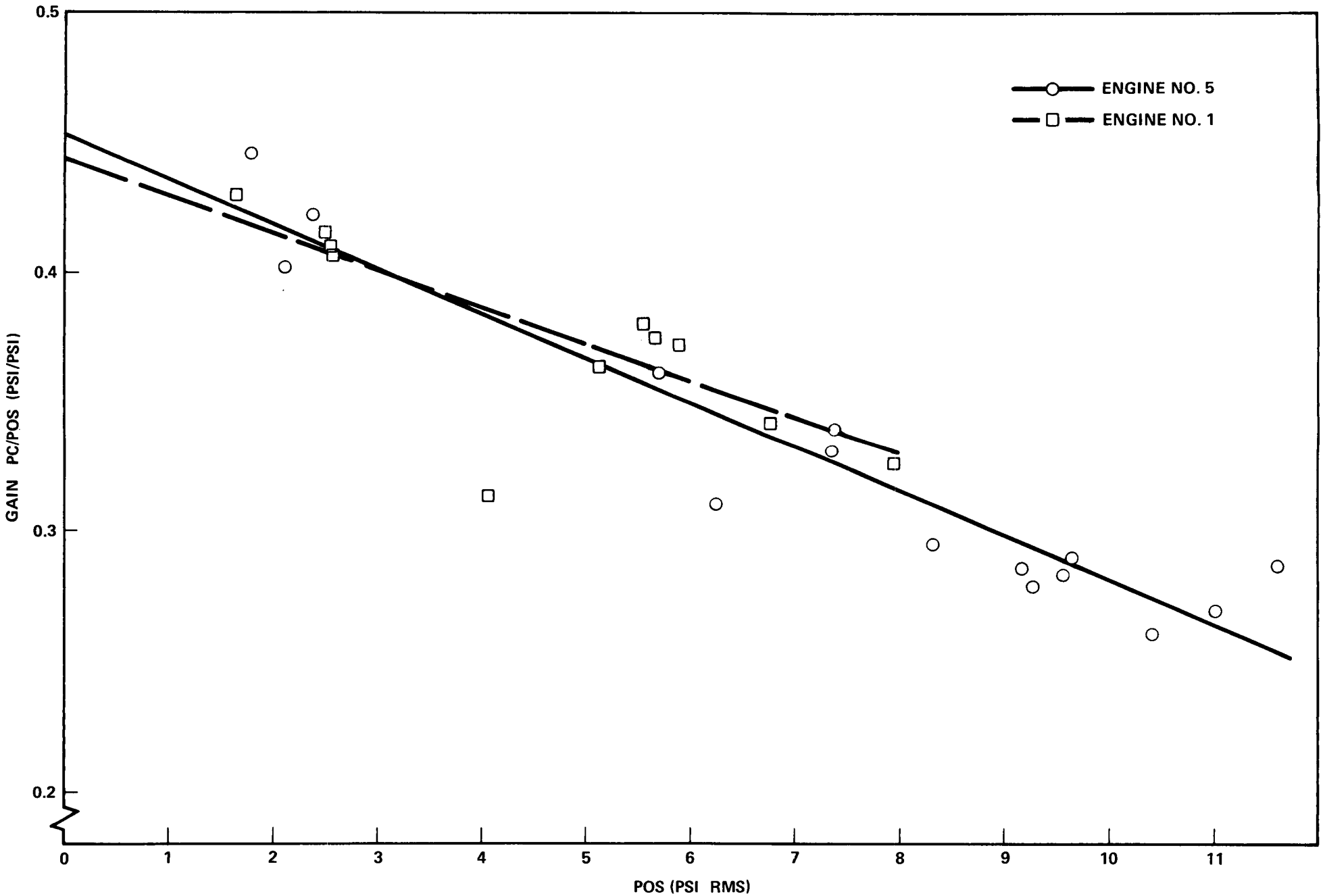

FIGURE 3 - SA-507 S-II ENGINE GAIN COMPARISON

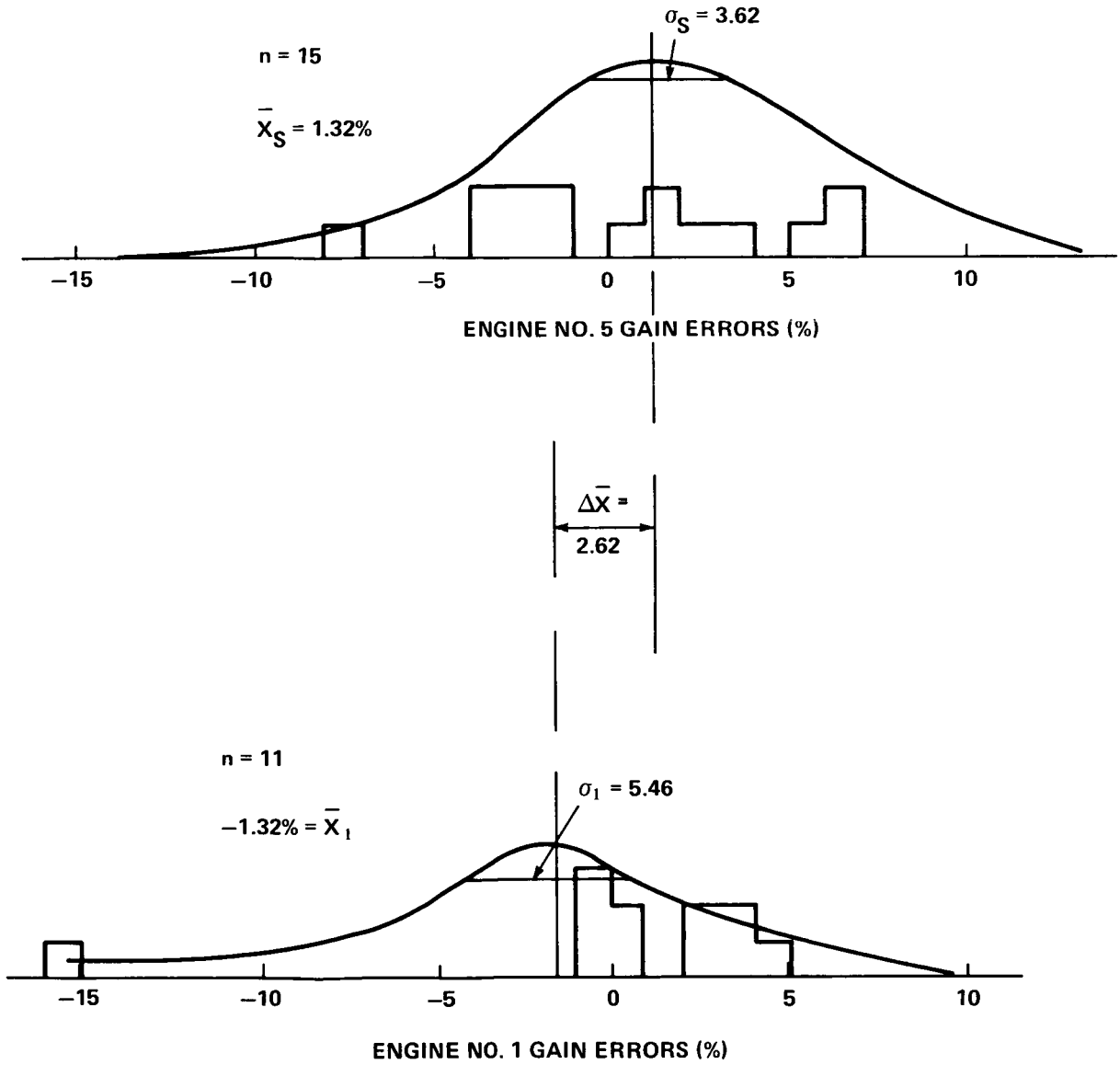

FIGURE 4 - SA–507 ENGINE 1 AND ENGINE 5 GAIN ERROR DISTRIBUTION

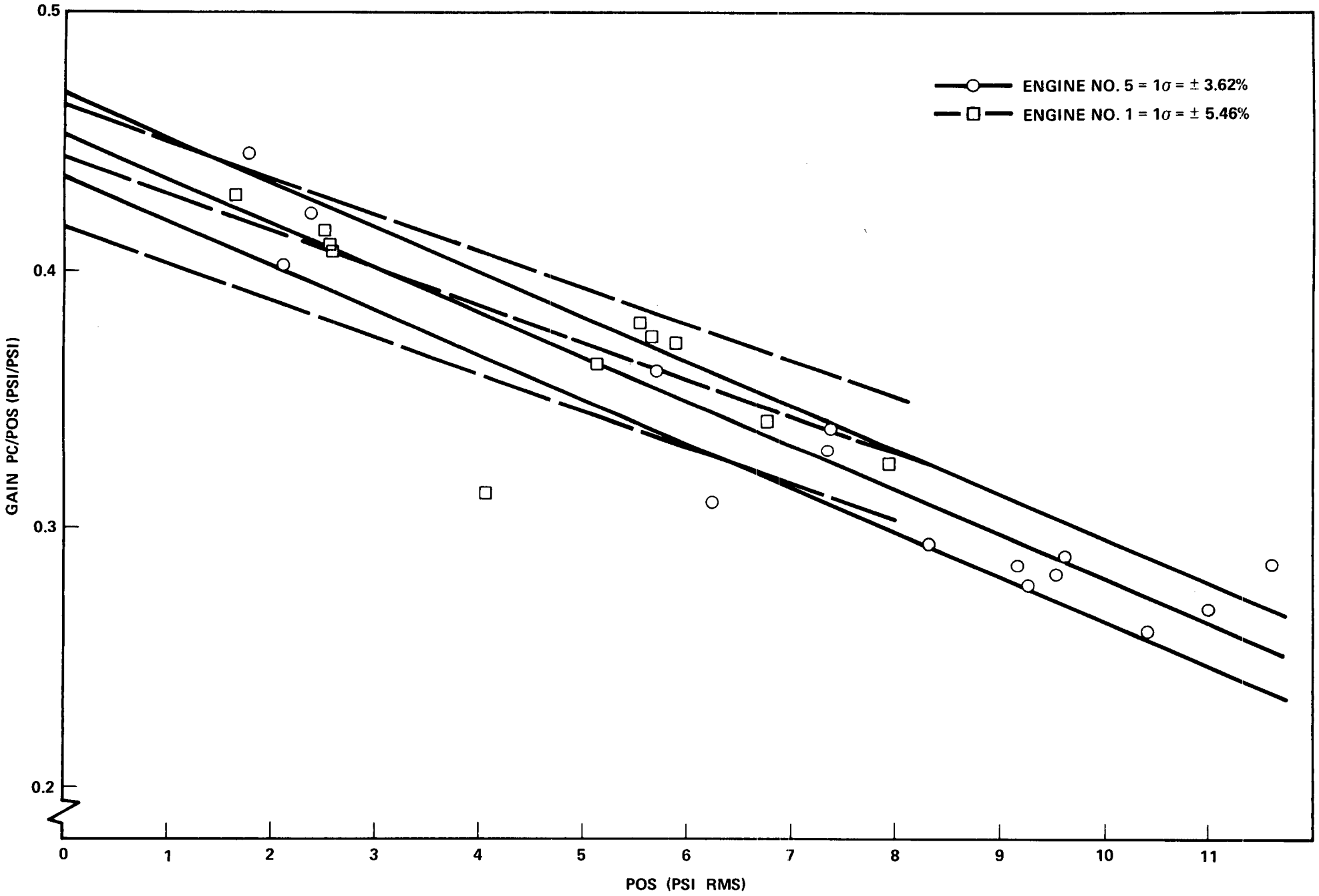

FIGURE 5 - SA-507 S-II ENGINE GAIN COMPARISON WITH ONE SIGMA LIMITS

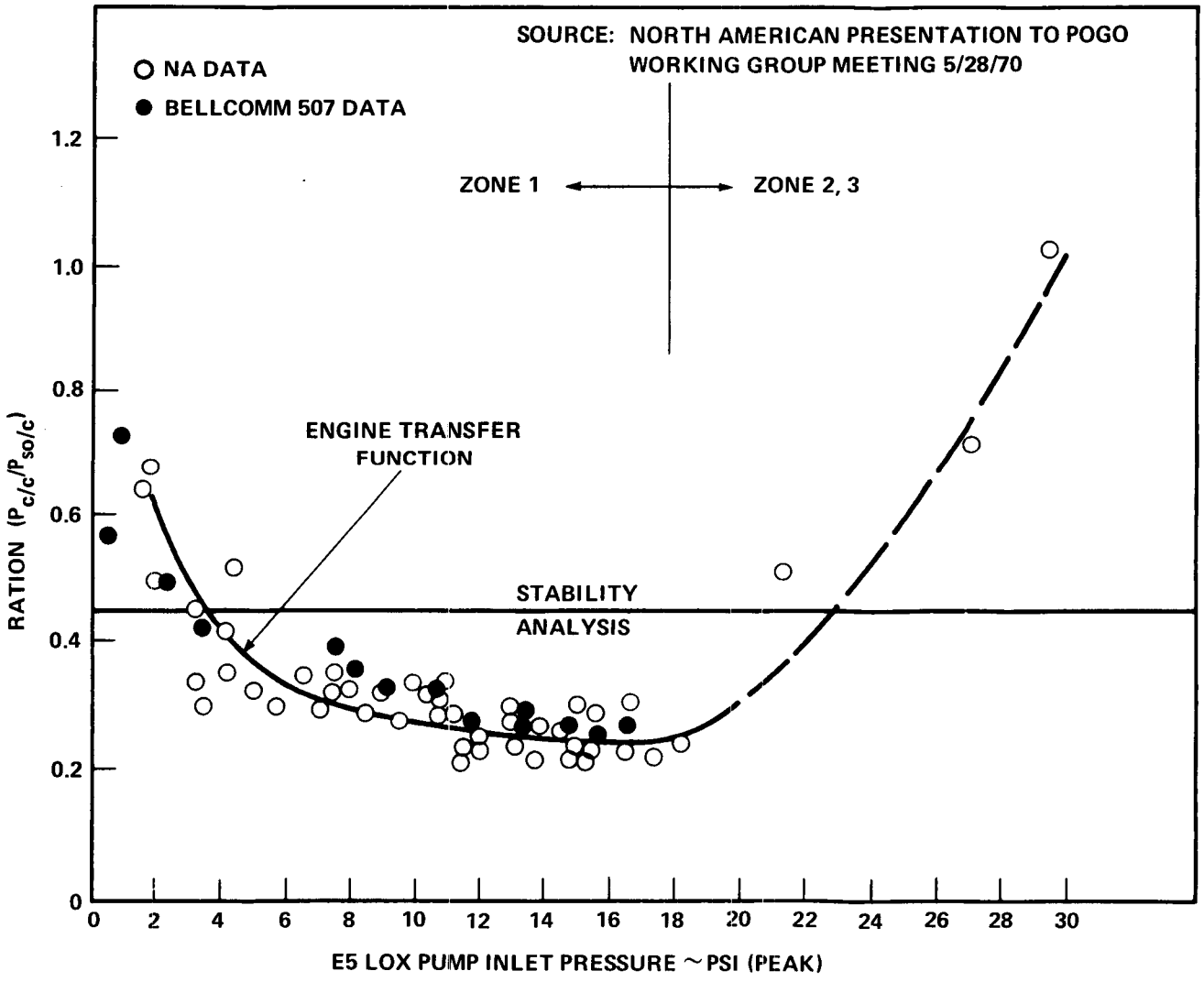

FIGURE 6 - AS-507 & AS-508 FLIGHT DATA E5 THRUST CHAMBER PRESSURE ($P_{c/c}$/E5 LOX PUMP INLET PRESSURE ($P_{so/c}$) TO E5 LOX PUMP INLET PRESSURE

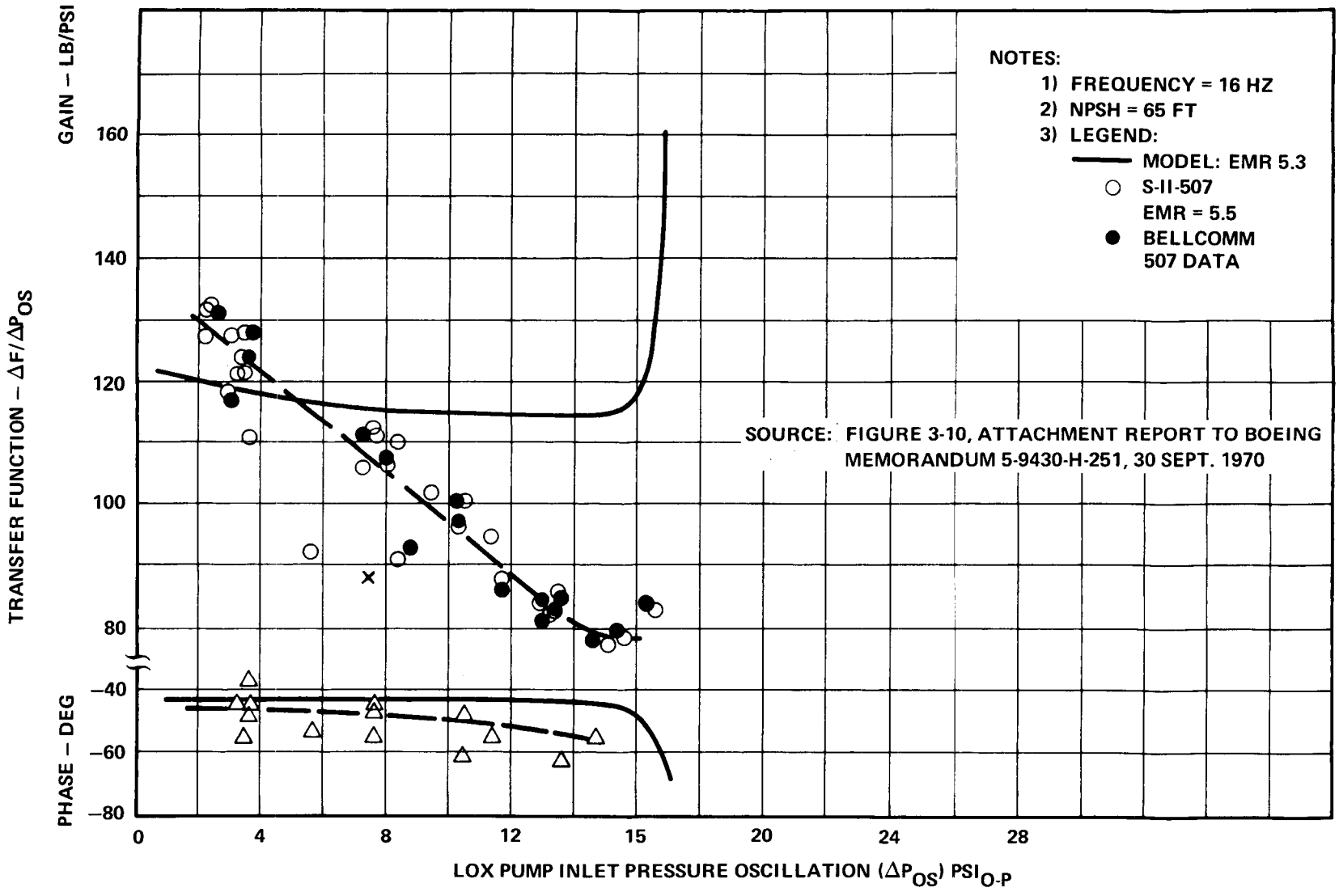

FIGURE 7 - COMPARISON OF S-II-507 FLIGHT AND J-2 ENGINE HYBRID MODEL DATA